VERIFICATION OF TRANSLATION

I, Eun-Jung Han of 901 Seoyoung Bldg., 158-12, Samsung-dong, Kangnam-ku, Seoul, 135-090, Korea, declare that I have a thorough knowledge of the Korean and English languages, and the writings contained in the following pages are correct English translation of the specification and claims of Korean Patent Application No. 2000-069850.

This 6th day of February, 2004

By:

Eun-Jung Han

[Eun-Jung Han]

KOREAN INTELLECTUAL

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[TITLE OF INVENTION IN KOREAN] 시분할 방식 액정표시장치 및 그의 컬러영상표시방법

[TITLE OF INVENTION IN ENGLISH] FIELD SEQUENTIAL LIQUID CRYSTAL DISPLAY DEVICE AND METHOD FOR COLOR IMAGE DISPLAY THE SAME

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[PURPORT] We submit application as above under the article 42 of the Patent Law.

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[FEES]

[BASIC APPLICATION FEE]	20 pages	29,000	won
[ADDITIONAL APPLICATION FEE]	20 pages	20,000	won
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[ENCLOSED] 1. Abstract, Specifications (with Drawings)_1 set

[DOCUMENT OF ABSTRACT]

[ABSTRACT]

A. Technical field of the invention stated in the range of claims

Field sequential liquid crystal display device and method for color image display the same

B. Technical subject to be solved by the invention

A conventional field sequential liquid crystal display device displays color images by repeatedly turning ON and OFF a backlight, which includes three color light sources of R, G and B, at regular intervals without color filter layers. However, the field sequential liquid crystal display device has a limited range of the maximum brightness to be displayed, and has a problem that it is hard to emphasize a specific color.

C. Points of solutions of the invention

To solve the problems, in the field sequential liquid crystal display device of the present invention, R, G and B or C, M, and Y are used as light sources of a backlight, and a image signal processor of the present invention controls image signals, the lighting order, and combination of the light sources depending on characteristics of entire images. Thus, the range of the maximum brightness to be displayed can be increased or can be adjusted, whereby the device can be applied not only to TVs, where the brightness is important, but also to other display devices.

[REPRESENTATIVE FIGURE]

FIG. 6

[SPECIFICATIONS]

[NAME OF INVENTION]

Field sequential liquid crystal display device and method for color image display the same

[BRIEF EXPLANATION OF FIGURES]

FIG. 1 is a schematic cross-sectional view of a conventional liquid crystal display device.

FIG. 2 is a schematic cross-sectional view of a conventional field sequential liquid crystal display device.

FIG. 3 is a flow chart schematically showing an operation of a field sequential liquid crystal display device according to a conventional color image display method.

FIG. 4 is a graph showing a gray level of the emitted light depending on light sources during a frame of FIG. 3.

FIG. 5 is a graph of the lighting time of subframes, plotted as a function of the time according to each light source.

FIG. 6 is a schematic diagram illustrating a field sequential liquid crystal display device according to the present invention.

FIG. 7 is a graph showing a gray level of the emitted light depending on each light source in one frame according to a first embodiment of the present invention.

FIG. 8 is a graph showing the combination of the light sources in each subframe of FIG. 7.

FIG. 9 is a chromaticity diagram showing a general color gamut of R, G and B and C,

M and Y.

FIG. 10 is a graph showing the lighting order and the combination of the light sources in each subframe according to a second embodiment of the present invention using a C, M and Y mode.

FIG. 11 is a flow chart schematically showing a color image display method according to the second embodiment of the present invention.

FIG. 12 is a graph showing a brightness of the emitted light depending on R, G and B light sources during one frame when the color image, for example, has a strong Red (R) color according to a third embodiment of the present invention.

FIG. 13 is a graph showing a combination of the light sources in each subframe of FIG. 12.

FIG. 14 is a flow chart showing an algorithm according to a fourth embodiment of the present invention.

* Explanation of major parts in the figures *

100: liquid crystal panel	110: backlight
111: three light sources	120: image signal processor

[DETAILED DESCRIPTION OF INVENTION]

[OBJECT OF INVENTION]

[TECHNICAL FIELD OF THE INVENTION AND PRIOR ART OF THE FIELD]

The present invention relates to a liquid crystal display (LCD) device, and more particularly, to a field sequential liquid crystal display device and a color image display

method for the same.

A driving mechanism of a liquid crystal display (LCD) device uses optical anisotropy and polarization properties of liquid crystal. Since the liquid crystal has a thin and long structure, molecules of the liquid crystal are arranged to have a fixed direction. By applying an electric field to the liquid crystal, the arrangement direction of the molecules can be artificially controlled.

Therefore, if the arrangement direction of the liquid crystal molecules may be controlled by artificial means, the arrangement of the liquid crystal molecules may be changed, and images may be displayed by refracting light according to the arrangement direction of the liquid crystal molecules due to the optical anisotropy.

In these days, an active-matrix liquid crystal display (AM LCD) device, where thin film transistors as switching elements and pixel electrodes connected to the thin film transistors are arranged in a matrix form, is the most popular because of its high resolution and superiority in displaying moving images

Hereinafter, a conventional liquid crystal display device displaying images by the above driving mechanism will be described.

FIG. 1 is a schematic cross-sectional view of a conventional liquid crystal display device.

As shown in FIG. 1, the conventional liquid crystal display 10 consists of an upper substrate 20 as a color filter substrate and a lower substrate 40 as an array substrate which are spaced apart from and face each other, a liquid crystal layer 30 interposed between the upper and lower substrate 20 and 40, and a backlight 50 disposed under a back surface of the lower substrate and irradiating light.

A color filter 22 is disposed under a transparent substrate 1 of the upper substrate 20.

The color filter 22 includes red (R), green (G), and blue (B) cells 22a, which transmit light having a range of specific wavelengths and absorb light having other wavelengths, and a black matrix 22b, which controls gaps between the R, G and B cells 22a, blocks light in areas of the lower substrate 40 where arrangement of the liquid crystal cannot be controlled, and prevents light from going into a thin film transistor.

An upper transparent electrode 24, which functions as one electrode for applying a voltage to the liquid crystal, is formed under the color filter 22.

A thin film transistor T, which functions as a switching element, and a lower transparent electrode 42, which receives signals from the thin film transistor T and serves as another electrode for applying a voltage to the liquid crystal layer 30, are formed over a transparent substrate 1 of the lower substrate 40.

The thin film transistor T consists of a gate electrode, a source electrode and a drain electrode, which are not shown.

However, the conventional liquid crystal display device having the above structure has some problems as follows.

Firstly, because the transmissivity of the color filter is less than 33% so that a brighter backlight is required in order to display a color image effectively, which results in the increase of the power consumption.

Secondly, a material used for the color filter is expensive, resulting in an increase of the manufacturing cost of the liquid crystal display device.

To overcome these problems of the liquid crystal display device, a field sequential liquid crystal display (FS LCD) device, which displays a full color due to color light sources without the color filters, has been suggested.

The backlight of the conventional liquid crystal display device provides white light to

a liquid crystal panel, turning on constantly, whereas the FS LCD device displays the color image by sequentially and periodically turning on and off the light sources.

The field sequential method was introduced in 1960, but was hard to be realized because a liquid crystal mode having a short response time and light sources corresponding to the response time of the liquid crystal are required.

However, a field sequential liquid crystal display device, which uses a liquid crystal mode having a short response time, such as Ferroelectric Liquid Crystal (FLC), Optical Compensated Birefringent (OCB) or Twisted Nematic (TN), and an R, G and B backlight turned on and off rapidly, has been proposed.

Especially, the Optical Compensated Birefringent (OCB) mode is generally used for the field sequential liquid crystal display device because the OCB mode forms a bend-structure and the response time thereof is less than about 5 msec when the voltage is applied thereto. Therefore, liquid crystal cells of the OCB mode are suitable for the field sequential liquid crystal display device owing to the short response time leaving no residual image on a screen.

FIG. 2 is a schematic cross-sectional view illustrating the conventional field sequential liquid crystal display device.

As shown in FIG. 2, the conventional field sequential liquid crystal display device 60 includes an upper substrate 64, a lower substrate 66 as an array substrate, a liquid crystal layer 70 interposed between the upper and lower substrates 64 and 66, and a backlight device 72 consisting of Red (R), Green (G) and Blue (B) light sources to irradiate light to a liquid crystal panel 62, which includes the upper substrate 64, the lower substrate 66 and the liquid crystal layer 70.

Upper and lower transparent electrodes 65 and 67 are formed on surfaces of the

upper and lower substrates 64 and 66 facing the liquid crystal layer 70, respectively, as electrodes for applying voltage to the liquid crystal layer 70.

A black matrix 61 is formed between a transparent substrate 1 of the upper substrate 64 and the upper transparent electrode 65 in order to prevent leakage of light in a non-display region other than a region for the lower transparent electrode 67.

A thin film transistor T, which functions as a switching element and is electrically connected to the lower transparent electrode 67, is formed over a transparent substrate 1 of the lower substrate 66. The thin film transistor T corresponds to the black matrix 61 of the upper substrate 64.

The thin film transistor T consists of gate, source and drain electrodes (not shown).

The biggest difference of the field sequential liquid crystal display (FS LCD) device 60 with the conventional liquid crystal display is that the FS LCD device does not need the color filters and has a backlight device that includes three different light sources that are sequentially and selectively turned on and/or off.

In driving the backlight device 70, the light sources having Red (R), Green (G) and Blue (B) colors are driven respectively by an inverter (not shown) and each of Red, Green and Blue light sources is turned on and off sixty times per second, resulting in one hundred and eighty times per second in all. Therefore, a color image caused by the mixture of three colors (red, green and blue) is displayed using an afterimage (i.e., residual image) effect of human vision.

Though the Red, Green and Blue light sources are turned on and off one hundred and eighty time per second, the perception by the naked eye is that the light sources are kept on due to the afterimage (or residual image) effect.

For example, if the Red light source is turned on and then the Blue light source is

sequentially turned on, a mixed color (i.e., violet) is shown owing to the residual image effect.

Since the FS LCD devices do not need the color filters, the FS LCD devices overcome the problem that the conventional active-matrix liquid crystal display devices cause the decrease of the luminance due to the color filters. In addition, the FS LCD devices are suitable for the liquid crystal display devices of a large scale because they can display a full-color using three-color light sources whereby they can display an image of high luminance and high resolution.

Though the conventional active-matrix liquid crystal display device is inferior to CRT (Cathode Ray Tube) in terms of price or resolution, the field sequential liquid crystal display device can solve these problems.

FIG. 3 is a flow chart schematically showing an operation of a field sequential liquid crystal display device according to a conventional color image display method.

In step st1, a single frame as an image display unit is divided into three subframes each having one - one hundred eightieth of a second (1/180 second) period.

In step st2, electric signals are applied to pixels of the FS LCD panel for forming images at 1/180 second interval as a period of the subframe according to st 1.

At this time when the electric signals are applied, the thin film transistors are operated as switching devices such that the liquid crystal molecules are arranged according to the signals. Further within one frame, the primarily arranged liquid crystal molecules of one pixel continue to maintain their status until the liquid crystal molecules of the last pixel are arranged.

In step st3, when the liquid crystal molecules of the designated frame are all arranged, the light sources are turned on in the designated pixel.

Namely, the light sources of the backlight device of the conventional FS LCD device

are turned on sequentially, respectively, periodically and repeatedly without the additional control devices.

FIG. 4 is a graph showing a gray level of the emitted light depending on light sources during a frame of FIG. 3.

In general, the liquid crystal panel for the FS LCD device does not include the color filter contrary to the conventional LCD device, such that the liquid crystal panel displays a black color unless the light source irradiates light. The gray level of the initially inputted signal is defined by multiplying a gray level of the black-and-white liquid crystal panel by a gray level of backlight.

As shown in FIG. 4, the brightness of the emitted light from Red, Green and Blue light sources, which are sequentially turned on/off during one frame 1f, is respectively represented by L1, L2 and L3.

That is, if the gray level of inputted signal and the gray level of black liquid crystal level are maintained at fixed values, it is obvious the picture brightness depends on the backlight.

However, since the Red, Green and Blue light sources are sequentially turned on and off in the conventional FS LCD devices without extra control devices, if the maximum brightness is limited to 1b that represents the brightness L2, and the maximum brightness to be shown is within $1b\pm\alpha$.

FIG. 5 is a graph of the lighting time of subframes, plotted as a function of the time according to each light source.

As shown in FIG. 5, 1/60 second as one frame 1f is divided into first sf1, second sf2 and third sf3 subframes of 1/180 period. At this time, each Red (R), Green (G) or Blue (B) light source of the subframes is substantially turned on for less than 1/180 second.

As stated in FIG. 3, the duration of each subframe sf1, sf2 or sf3 takes into account the duration of applying the electric signal, aligning the liquid crystal molecules and turning on the backlight device. Therefore, if each light source of the subframe is thoroughly turned on for 1/180 second, the light leakage can occur because the light is irradiated before the aligning of the liquid crystal molecules. Furthermore, the color interference may occur between the light sources of the subframes.

In other words, switching on and off the light source of each subframe is carried out after applying the electric signals and aligning the liquid crystal molecules, and depends on the thin film transistors and the condition of the liquid crystal molecules.

However, since the conventional FS LCD devices does not have a control device controlling the light sources of the backlight device, the light leakage and the decrease of display quality occur in the conventional FS LCD devices whenever the design of the thin film transistor changes.

[TECHNICAL SUBJECT OF INVENTION]

To solve the problems, an object of the present invention is to provide a field sequential liquid crystal display (FS LCD) device and a color image display method thereof that includes an image signal processor controlling image signals and on/off of three color light sources of a backlight device, thereby displaying appropriate images depending on characteristics of displayed images.

[CONSTRUCTION AND OPERATION OF INVENTION]

To achieve the above-mentioned object, a field sequential liquid crystal display device includes a liquid crystal panel having an upper substrate, a lower substrate and liquid

crystal interposed therebetween; a backlight device under the liquid crystal panel for irradiating light to the liquid crystal panel and having three color light sources, wherein the three color light sources are separately lit in order; and an image signal processor controlling a lighting order and combination of the three color light sources.

The three color light sources are C(Cyan), M(Magenta) and Y(Yellow) light sources or R(Red), G(Green) and B(Blue) light sources.

The image signal processor changes image signals provided to the liquid crystal panel and the lighting order and combination of the light sources of the backlight device depending on characteristics of a displayed image, and the liquid crystal is an Optically Compensated Birefringence (OCB) mode having a bend structure when voltage is applied or a Ferroelectric Liquid Crystal (FLC) mode.

In the device, the three color light sources are sequentially lit at three subframes of 1/180 second period, respectively, when one frame period for displaying an image is approximately 1/60 second.

A lighting time of each of the light sources at each subframe is less than 1/180 second.

In another aspect of the present invention, a color image display method for a field sequential liquid crystal display device that includes a liquid crystal panel having an upper substrate, a lower substrate, a liquid crystal layer therebetween, and black and white pixels on the lower substrate as elements for forming an image; a backlight device under the liquid crystal panel for irradiating light to the liquid crystal panel and having R, G and B light sources, wherein the R, G and B light sources are separately lit in order; and an image signal processor controlling a lighting order and combination of the R, G and B light sources, the method comprising the steps of dividing one frame for displaying an image into three

subframes, wherein each subframe has a substantially same period; applying to each black and white pixel through the image signal processor depending on characteristics of a displayed image; and lighting the R, G and B light sources by changing the combination of the R, G and B light sources turned on at each subframe through the image signal processor.

The combination of the light sources turned on each subframe is one of sequential combinations consisting of C(B+G), M(R+B) and Y(R+G), when in the charateristics of the displayed image, the displayed image requires a high white brightness. One frame period is approximately 1/60 second, and a lighting time of each of the light sources at each subframe is less than about 1/180 second.

The image signal processor converts the image signal into an image signal corresponding to a C-M-Y mode when the R, G and B light sources lit at one frame are used as the C-M-Y mode, and applies the converted image signal data to the subframes, wherey the R, G and B light sources are sequentially lit at each subframe by the converted image singal data in accordance with the C-M-Y mode.

The number of lighting the light source corresponding to an emphasized color is increased when in characteristics of the displayed image, the displayed image need the emphasized color.

The R light sources is turned on not only at a first subframe but also at least one of second and third subframes when the emphasized color is Red. In a color image display algorithm of the field sequential liquid crystal display device, further comprising steps of expressing R, G and B with a gray level having 256 levels before applying the image signal; setting it as a maximum brightness that each brightness of R, G and B has a value of gray level of at least 127 in the black and white pixel; calculating an average brightness value of each R, G and B for the displayed image; classifying cases in accordance with the image

signal by which the average brightness values of the R, G and B is greater than the maximum brightness of the displayed image; and determining which light sources are turned on at the subframes in each case.

The number of the R, G and B light sources turned on at each subframe is less than two, and classifying the cases depends on a range of the average brightness values of the R, G and B.

Turning on the light sources additionally at each subframe is determined by a value that doubles respective minimum values of the R, G and B when the brightness of the displayed image is important in the charateristics of the displayed image.

The liquid crystal is an Optically Compensated Birefringence (OCB) mode having a bend structure when voltage is applied or a Ferroelectric Liquid Crystal (FLC) mode.

FIG. 6 is a schematic diagram illustrating a field sequential liquid crystal display (FS LCD) device according to the present invention.

As shown in FIG. 6, the FS LCD of the present invention comprises a liquid crystal panel 100 consisting of upper and lower substrates, a backlight device 110 placed below the liquid crystal panel 100 and including three color light sources 111, which are separately lit in order, and an image signal processor 120 controlling the lighting order and combination of the three color light sources 111.

The liquid crystal panel 100 has the same structure and configuration as the liquid crystal panel of the conventional FS LCD as shown in FIG. 2.

The three color light sources 111 of the backlight device 110 have one of Red, Green and Blue light sources or C(Cyan), M(Magenta) and Y(Yellow) light sources.

The image signal processor 120 controls the backlight device 110 and the image signals applied to the pixel of the liquid crystal panel 100, thereby maximizing the brightness

and increasing the brightness of the desired color.

For the liquid crystal of the present invention, Ferroelectric Liquid Crystal (FLC), Opitcally Compensated Birefringent (OCB) liquid crystal or Twisted Nematic (TN) liquid crystal is used.

Further, the backlight device 110 of the present invention is one of the wave guide type and the direct type depending on the location of the light sources.

The wave guide type backlight device has the light sources disposed at one edge or both edges of the liquid crystal panel 100, and the direct type backlight device has light sources horizontally disposed in a repeated sequence such as R, G, B, R, G, B, ... under the liquid crystal panel 100.

The backlight device of the present invention is selected from one of the above backlight type.

The present invention will be explained hereinafter in detail in exemplary embodiments.

< embodiment 1 >

In a first embodiment of the present invention, the backlight device has three color light sources Cyan (C), Magenta (M) and Yellow (Y).

The Cyan (C), Magenta (M) and Yellow (Y) light sources consist of the color combinations of Blue (B) + Green (G), Red (R) + Blue (B) and Red (R) + Green (G), respectively. Since the light efficiency of the C, M and Y light sources is twice as much as that of the R, G and B light sources, the maximum brightness of the image can be increased.

FIG. 7 is a graph showing a gray level of the emitted light depending on each light source in one frame 1F according to a first embodiment of the present invention.

As shown in FIG. 7, the C, M and Y light sources of the backlight device are

sequentially turned on in one frame 1F, and the gray levels of the emitted light are represented by L1', L2' and L3', respectively.

At this point, since the light efficiency of the C, M and Y light sources is twice as much as that of R, G and B light sources, the maximum gray level L2' is twice as large than L2 of FIG. 4. Therefore, the maximum gray level L2' is represented by 2b.

That is, since the C, M and Y light sources has a chromaticity close to white rather than the R, G and B light sources, the C, M and Y light sources have the higher brightness than the R, G and B light sources. Therefore, it is possible that the maximum brightness to display increases.

FIG. 8 is a graph showing the combination of the light sources in each subframe of FIG. 7.

As shown in FIG. 8, the C, M and Y light sources according to the first embodiment are turned on at each subframe in order.

At this time, the lighting time of the light source at a subframe is equal to that of FIG. 5, and the C, M and Y light sources are turned on for less than 1/180 second to one frame of 1/60 second, respectively.

That is, as described in FIG. 7, the brightness of the C, M and Y light sources is twice as much as the conventional art, and the C, M and Y light sources are sequentially lit at regular intervals.

Accordingly in the FS LCD device according to the first embodiment of the present invention, the C, M and Y light sources are used and the image signal processor controls the image signals to be suitable for the C, M and Y light sources, thereby controlling the gray levels of the displayed colors of the images.

< embodiment 2 >

In a second embodiment of the present invention, the backlight device uses Red (R), Green (G) and Blue (B) light sources as the three color light sources. Further, the image signal processor controls the image signals and the lighting order and combination of the R, G and B light sources, whereby a R-G-B mode and a C-M-Y mode can selectively be used depending on characteristics of a displayed image.

In the R-G-B mode, the R, G and B light sources are sequentially lit at each subframe, and in the C-M-Y mode, two of the R, G and B light sources, for example, G+B, R+B, and R+G, are sequentially turned on at each subframe.

That is, Accordingly, the R-G-B mode can be converted in the C-M-Y mode and the C-M-Y mode in the R-G-B mode using the image signal processor of the present invention. Additionally at the time of the conversion, the image signals applied to the pixel and the lighting order and combination of the R, G and B light sources are appropriately controlled.

FIG. 9 is a schematic diagram showing color coordinates of a general color gamut of R, G and B and C, M and Y.

As shown in FIG. 9, an outer parabolic area of the color gamut represents the color range the human eye can perceive, and triangular areas consisting of C-M-Y and R-G-B coordinates represent the chromaticity coordinates to be displayed.

Namely, although the C, M and Y have better light efficiency than the R, G and B, the color gamut of the C, M and Y is narrower than the R, G and B. Therefore, if the backlight device includes only one of the R-G-B mode and C-M-Y mode light sources, it is difficult to satisfy both the light efficiency and color reproduction of the FS LCD device.

FIG. 10 is a graph showing the lighting order and the combination of the light sources in each subframe according to a second embodiment of the present invention using a C-M-Y mode

As shown in FIG. 10, in the lighting order and the combination of the light sources according to a second embodiment using the C-M-Y mode, the B and G light sources are simultaneously turned on in a first subframe SF1, the R and B light sources are simultaneously turned on in a second subframe SF2, and the G and R light sources are simultaneously turned on in a third subframe SF3 for one frame 1F.

That is, if the light sources are lit according to the C-M-Y mode, the brightness of the displayed pictures increases over that in the R-G-B mode.

FIG. 11 is a flow chart schematically showing a color image display method according to the second embodiment of the present invention.

At this time, it is noticeable that the single frame of the field sequential liquid crystal display device as a unit for displaying images includes three subframes as stated before.

In step ST1, a single frame having a periodicity of 1/60 second is divided into three subframes each having one - one hundred eightieth of a second (1/180 second) period.

In step ST2, the image signal processor selects one of the R-G-B mode and the C-M-Y mode by measuring characteristics of a displayed image. Thus, the image signals applied to the pixels is controlled by this image signal processor in accordance with the selected mode.

In step ST3, the image signal processor controls the lighting order and combination of the light sources of the backlight device, in accordance with the image signals of the step ST2.

In step ST4, the one or two light sources of the backlight device are turned on in each subframe depending on results of the step ST3.

Although the above-described light sources of the backlight device are lit respectively and repeatedly by subframe period, these light sources of the subframes is sensed by the human eye as one frame.

Additionally in the color image display method of the FS LCD device according to the present invention, since the number of the light sources is adjustable, the maximum brightness of the FS LCD device can be increased.

In the FS LCD device according to the second embodiment of the present invention, if the displayed picture requires the higher brightness close to white color, the C-M-Y mode is selected, and if the color reproduction needs to be expanded rather than increasing the light efficiency, the R-G-B mode is selected.

In other words, since the image signal processor can control the image signal and turn on/off the light sources depending on the characteristics of the display pictures, the FS LCD of the second embodiment can be utilized in various display devices.

< embodiment 3 >

A third embodiment of the present invention relates to a method displaying images emphasizing a certain color.

The FS LCD device of the third embodiment includes the R, G and B light sources in the backlight device similarly to the second embodiment, and these R, G and B light sources are sequentially lit in each subframe. When the certain color needs to be emphasized, the image signal processor also controls the image signals and the lighting order and combination of the R, G and B light sources.

FIG. 12 is a graph showing a brightness of the emitted light depending on R, G and B light sources during one frame when the color image, for example, has a strong Red (R) color according to the third embodiment of the present invention

As shown in FIG. 12, when the color image picture has a strong Red (R) color, the Red light source is turned on not only in the first frame but also in the second and third frames. Therefore, the emitted brightness of the light sources are represented by L1'+L2'+L3'(R),

L2'(G) and L3'(B), respectively. Namely, in order to emphasize the R color, the R light source is turned on in all subframes, and thus, the brightness of the Red (R) color is three times higher than the Green (G) and Blue (B) light sources.

Accordingly in the third embodiment, when compared to the brightness value I that is the maximum brightness of one light source, the range of the maximum brightness increase and is more expanded in display.

FIG. 13 is a graph showing a combination of the light sources in each subframe of FIG. 12.

As shown in FIG. 13, when the color image has the strong R color, the R light source is turned on not only in the first subframe SF1 but also in the second and third subframes SF2 and SF3 during one frame 1F.

That is, as stated with FIG. 12, since the R light source is turned on in all subframes, the brightness of the R light source increases maximum three times. The G and B light sources are respectively turned on in the second SF2 and third SF3 frames, and thus the brightness of the desired color, e.g., Red (R) color, can be emphasized and increased.

However, in the present invention, although the light source of the emphasized color may be turned on in all subframes, it is possible that the light source of the emphasized color can be additionally turned on in one subframe besides the corresponding subframe.

Therefore, the maximum brightness of the desired color can also be increased according to the third embodiment.

< embodiment 4 >

In a fourth embodiment of the present invention, the second embodiment and the third embodiment are utilized and combined. Depending on the color image characteristics, the image signal processor of the fourth embodiment controls the image signals and the on/off

of the light sources.

That is, the color image is classified into (1) the image that needs to be displayed by the R-G-B mode, (2) the image that needs to be displayed by the C-M-Y mode due to high white brightness of the displayed image, and (3) the image that needs to be displayed by emphasizing a certain color. Thus, the image signal processor controls the image signals and the on/off of the light sources by selecting one of the above-mentioned images.

For more detailed explanation, when converted into the R-G-B mode or the C-M-Y mode, the image signal is represented as follows:

$$R+G=Y/2$$

$$G+B=C/2$$

$$B+R=M/2$$

Namely, since the Cyan (C), Magenta (M) and Yellow (Y) have the high brightness rather than the Red (R), Green (G) and Blue (B), the relation between the R-G-B mode and the C-M-Y mode is expressed by the above-mentioned equations in order to control the image signal within the same conditions.

As the brightness of the colors that human beings perceive is different from each other and is not increased linearly, the image signal should be converted depending on the color in order to be matched with the light source of the backlight device whenever each light source is turned on and off to have different periods.

Suppose that the gray level of the ambient light is A1, the gray level substantially shown in the display panel is A2, and the brightness of the backlight is A3. The gray level A1 is equal to the gray level A2 (i.e., A1=A2) in the conventional liquid crystal display device having the color filters. However, in the FS LCD device of the present invention, the gray lever A1 is represented by A1=A2+A3 because the color image is displayed by the color light

sources and the liquid crystal panel having no color filters.

Accordingly, whenever the sequential lighting method of the light sources changes, the image signal also changes.

That is, since the image signal processor according to the present invention makes the multiplied gray level A2+A3 be matched with the gray level A1, the high brightness and the high definition are obtained.

FIG. 14 is a flow chart showing an algorithm according to a fourth embodiment of the present invention.

In the algorithm, the brightness of each component R, G and B in color image signal is expressed with a gray level having 256 levels. When the brightness of each component R, G and B has a value of gray level 127 in pixels of the liquid crystal panel, it is set as a maximum brightness.

Dividing the gray level into 256 levels is a current standard, and more than levels are not distinguished.

Additionally, the inputted signals generally have an influence on the gray level of the liquid crystal display device.

In step ST1, an average brightness value Ra, Ga and Ba of each of components R, G and B is calculated for a full screen.

In step ST2, the light source that is turned on at each subframe is selected depending on each case.

In this step, the image signals and the lighting order and combination of the R, G and B light sources are controlled by the image processor according to the present invention.

For convenience of explanation, the On-state of the light source at each subframe is represented by "1", while the Off-state is represented by "0".

In case 1, the average brightness values of components R, G and B are all more than gray level 127.

At this time, the combinations of the R, G and B light sources within one frame are (1, 1, 0), (1, 0, 1) and (0, 1, 1), respectively, at each first, second and third subframes.

In other words, the R light source is turned on in both the first and second subframes, the G light source in both the first and third subframes, and the B light source in both the second and third subframes.

Additionally, although the R, G and B light sources are all turned on in all subframes, the color range may become narrow at this time.

Case 2 represents that the average brightness values of the components G and B are more than gray level 127, Case 3 represents that the average brightness values of the components R and B are more than gray level 127, and Case 4 represents that the average brightness values of the components R and G are more than gray level 127.

In addition, Case 5 represents that the average brightness value of the component R is more than gray level 127, Case 6 represents that the average brightness value of the component G is more than gray level 127, and Case 7 represents that the average brightness value of the component B is more than gray level 127.

Finally, Case 8 represents that the average brightness values of the components R, G and B are all less than the gray level 127. At this case, only one light source is sequentially turned on at each subframe.

In Cases 2 to 6, the combination of the turned-on light sources depends on the range of the average brightness values of the components R, G and B.

In step ST3, the image signal applied to each pixel changes depending on each case.

As compared with the combination of the light sources, i.e., (R, G, B), that are turned

on at each subframe of the conventional field sequential liquid crystal display device, the combination of the light sources according to the fifth embodiment is expressed as follows.

Case 1 has the combination (R+G, G+B, B+R), Case 2 has the combination (R+G, B B+G), and Case 5 has the combination (R, R+G, R+B). Furthermore, Case 8 has the combination (R, G, B) the same as the conventional device.

In Cases 2 to 6, the image signal conversion equations may change depending on the average brightness values of the R, G and B for the full screen.

< embodiment 5 >

Cases 1 to 7 have a problem that the color gamut for displaying image becomes narrow as compared with the Case 8 of the algorithm according to the fourth embodiment. To overcome this problem, a fifth embodiment of the present invention is introduced.

Namely, to improve the problem, the minimum values of the components R, G and B in chromaticity coordinates are first calculated, and then the minimum values are doubled. When turning on and off the light sources, the lighting of the light sources is determined depending on these doubled values, thereby preventing the problem that there are colors not to be displayed.

Further if the high brightness is required in display, the color distribution of the image can be changed according to the color gamut.

< embodiment 6 >

In a sixth embodiment, the above-mentioned field sequential mode of the present invention can be utilized in the other display devices except for the liquid crystal display device.

As the other display devices, there are DMD(Digital Micromirror Device) developed by TI (Texas Instruments Technology) and a liquid crystal display (LCD) projector, for

example.

The liquid crystal display (LCD) projector is one of color image display devices which enlarges and then projects various moving images or stationary images transmitted from electronic goods such as video player, television set and computer by about 300 inches using the liquid crystal display.

The field sequential method according to the presented invention mentioned in the first to fifth embodiments may be used as a light source system and method in the DMD or the liquid crystal display (LCD) projector.

[EFFECT OF INVENTION]

As described foregoing, since the image signals and the lighting order and combination of the light sources are controlled depending on the image characteristics according to the FS LCD device of the present invention, the maximum brightness is increased. Further, since the range of the maximum brightness is adjustable, the FS LCD device can be utilized in the other display devices.

[RANGE OF CLAIMS]

[CLAIM 1]

A field sequential liquid crystal display device, comprising:

a liquid crystal panel having an upper substrate, a lower substrate and liquid crystal interposed therebetween;

a backlight device under the liquid crystal panel for irradiating light to the liquid crystal panel and having three color light sources, wherein the three color light sources are separately lit in order; and

an image signal processor controlling a lighting order and combination of the three color light sources.

[CLAIM 2]

The device according to claim 1, wherein the three color light sources are C(Cyan), M(Magenta) and Y(Yellow) light sources.

[CLAIM 3]

The device according to claim 1, wherein the three color light sources are R(Red), G(Green) and B(Blue) light sources.

[CLAIM 4]

The device according to claim 1, wherein the image signal processor changes image signals provided to the liquid crystal panel and the lighting order and combination of the light sources of the backlight device depending on characteristics of a displayed image.

[CLAIM 5]

The device according to claim 1, wherein the liquid crystal is an Optically Compensated Birefringence (OCB) mode having a bend structure when voltage is applied or a Ferroelectric Liquid Crystal (FLC) mode.

[CLAIM 6]

The device according to claim 1, wherein the three color light sources are sequentially lit at three subframes of 1/180 second period, respectively, when one frame period for displaying an image is approximately 1/60 second.

[CLAIM 7]

The device according to one of claims 1 to 6, wherein a lighting time of each of the light sources at each subframe is less than 1/180 second.

[CLAIM 8]

A color image display method for a field sequential liquid crystal display device that includes a liquid crystal panel having an upper substrate, a lower substrate, a liquid crystal layer therebetween, and black and white pixels on the lower substrate as elements for forming an image; a backlight device under the liquid crystal panel for irradiating light to the liquid crystal panel and having R, G and B light sources, wherein the R, G and B light sources are separately lit in order; and an image signal processor controlling a lighting order and combination of the R, G and B light sources, the method comprising the steps of:

dividing one frame for displaying an image into three subframes, wherein each subframe has a substantially same period;

applying to each black and white pixel through the image signal processor depending on characteristics of a displayed image; and

lighting the R, G and B light sources by changing the combination of the R, G and B light sources turned on at each subframe through the image signal processor.

[CLAIM 9]

The method according to claim 8, wherein the combination of the light sources turned on each subframe is one of sequential combinations consisting of C(B+G), M(R+B) and Y(R+G), when in the charateristics of the displayed image, the displayed image requires a high white brightness.

[CLAIM 10]

The method according to claim 8, wherein one frame period is approximately 1/60 second.

[CLAIM 11]

The method according to one of claims 8 to 10, wherein a lighting time of each of the light sources at each subframe is less than about 1/180 second.

[CLAIM 12]

The method according to one of claims 8 and 9, wherein the image signal processor converts the image signal into an image signal corresponding to a C-M-Y mode when the R, G and B light sources lit at one frame are used as the C-M-Y mode, and applies the converted image signal data to the subframes, wherey the R, G and B light sources are sequentially lit at each subframe by the converted image singal data in accordance with the C-M-Y mode.

[CLAIM 13]

The method according to claim 8, wherein the number of lighting the light source corresponding to an emphasized color is increased when in characteristics of the displayed image, the displayed image need the emphasized color.

[CLAIM 14]

The method according to claim 8, wherein the R light sources is turned on not only at a first subframe but also at least one of second and third subframes when the emphasized color is Red.

[CLAIM 15]

The method according to claim 8, in a color image display algorithm of the field sequential liquid crystal display device, further comprising steps of expressing R, G and B with a gray level having 256 levels before applying the image signal; setting it as a maximum brightness that each brightness of R, G and B has a value of gray level of at least 127 in the black and white pixel; calculating an average brightness value of each R, G and B for the displayed image; classifying cases in accordance with the image signal by which the average brightness values of the R, G and B is greater than the maximum brightness of the displayed image; and determining which light sources are turned on at the subframes in each case.

[CLAIM 16]

The method according to claim 8, wherein the number of the R, G and B light sources turned on at each subframe is less than two.

[CLAIM 17]

The method according to claim 15, wherein classifying the cases depends on a range of the average brightness values of the R, G and B.

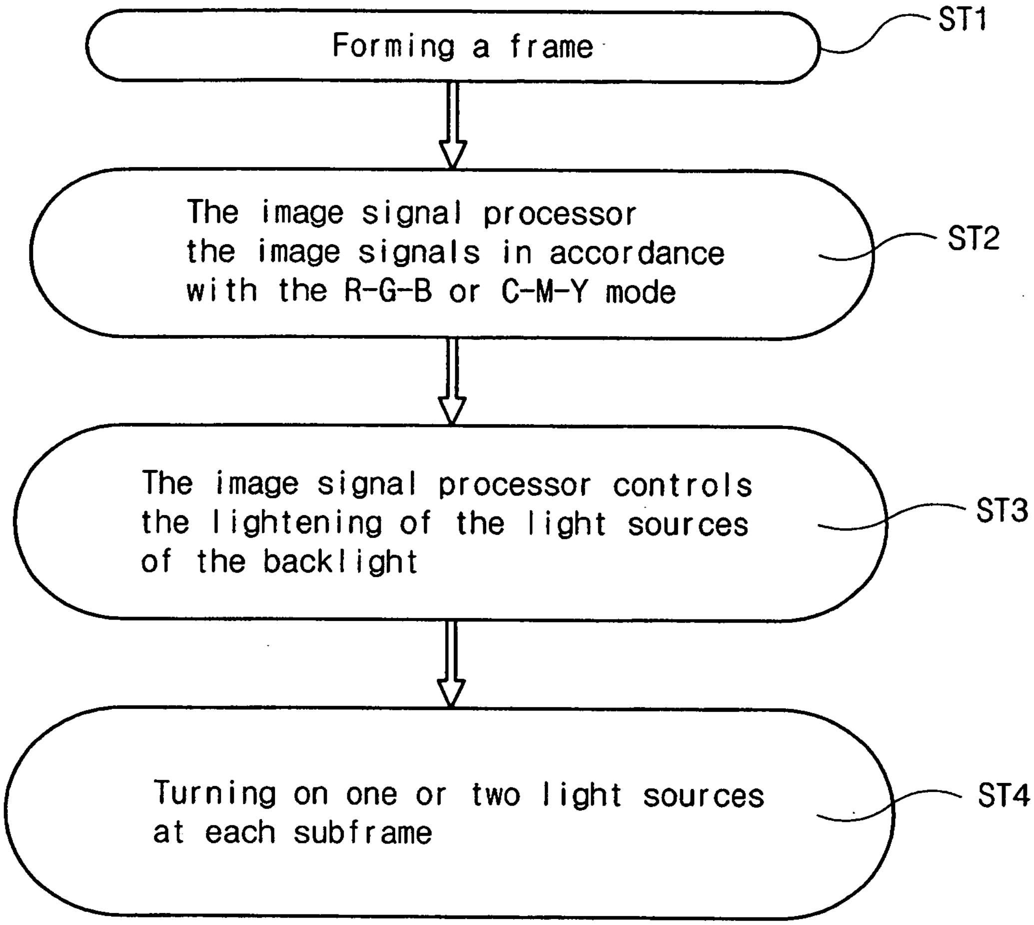
[CLAIM 18]

The method according to claim 8, wherein turning on the light sources additionally at each subframe is determined by a value that doubles respective minimum values of the R, G and B when the brightness of the displayed image is important in the charateristics of the displayed image.

[CLAIM 19]

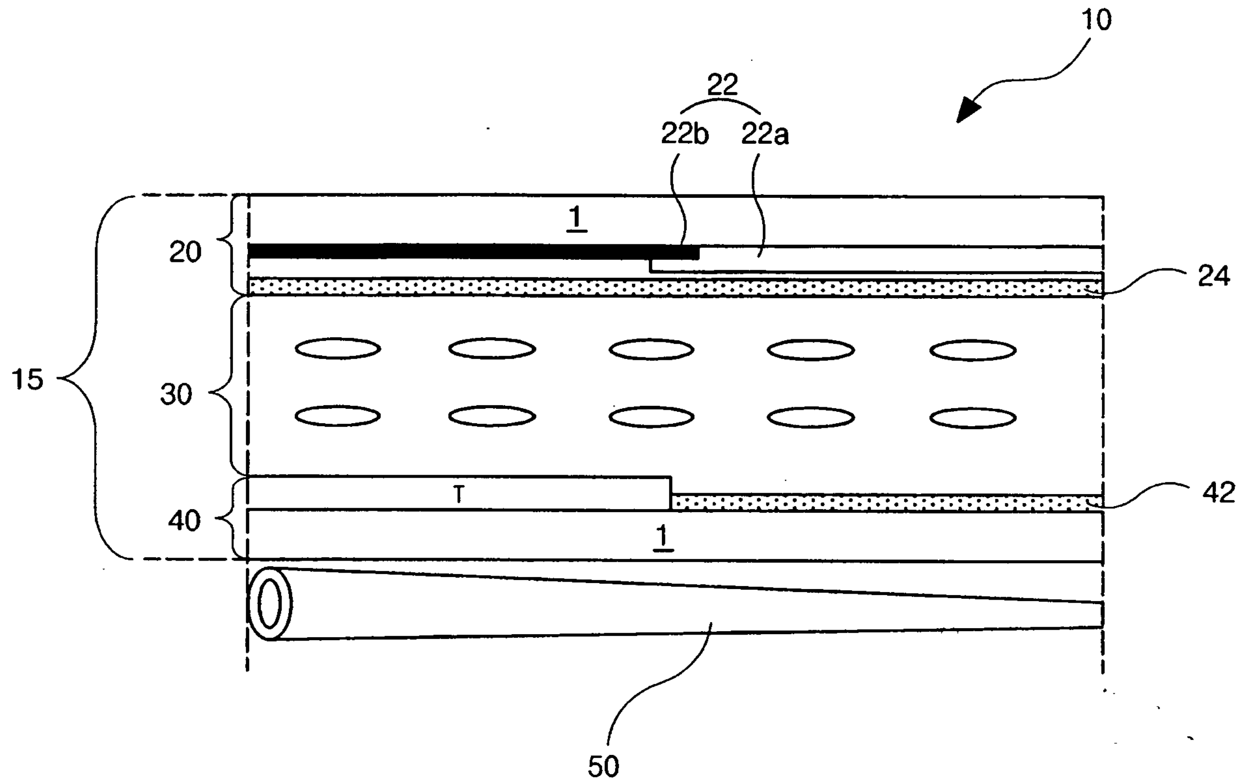
The method according to claim 8, wherein the liquid crystal is an Optically Compensated Birefringence (OCB) mode having a bend structure when voltage is applied or a Ferroelectric Liquid Crystal (FLC) mode.

[Fig. 11]

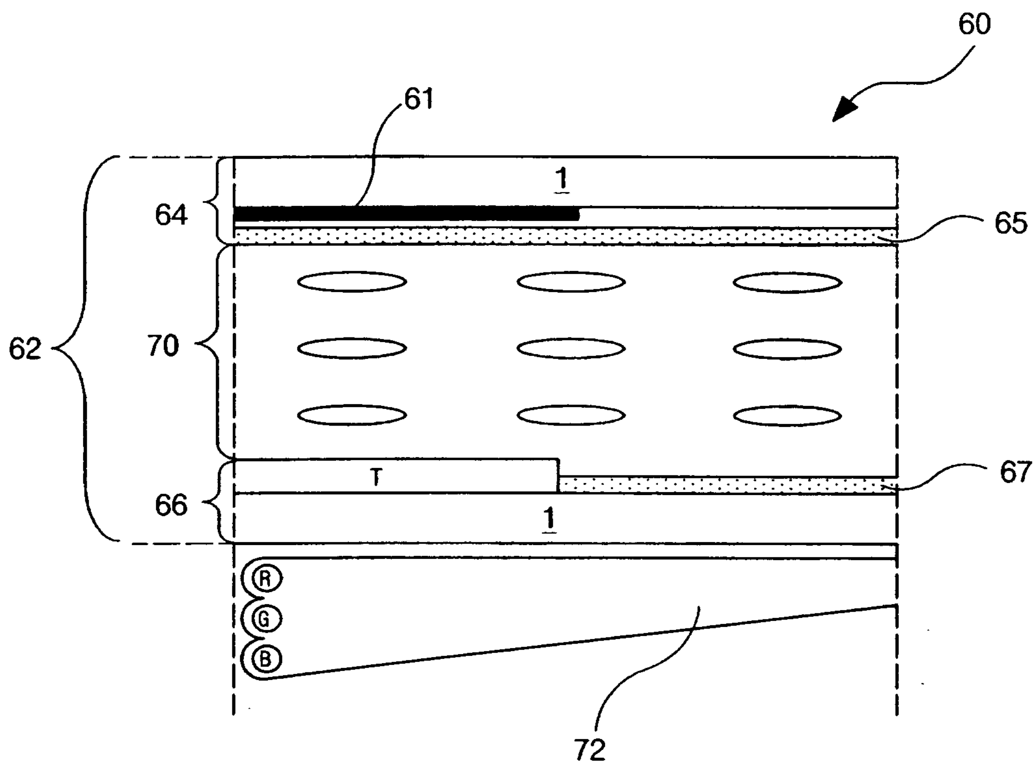

Forming a frame
ST1
The image signal processor
the image signals in accordance
with the R-G-B or C-M-Y mode
ST2
The image signal processor controls
the lightening of the light sources
of the backlight
ST3
Turning on one or two light sources
at each subframe
ST4

[DRAWINGS]

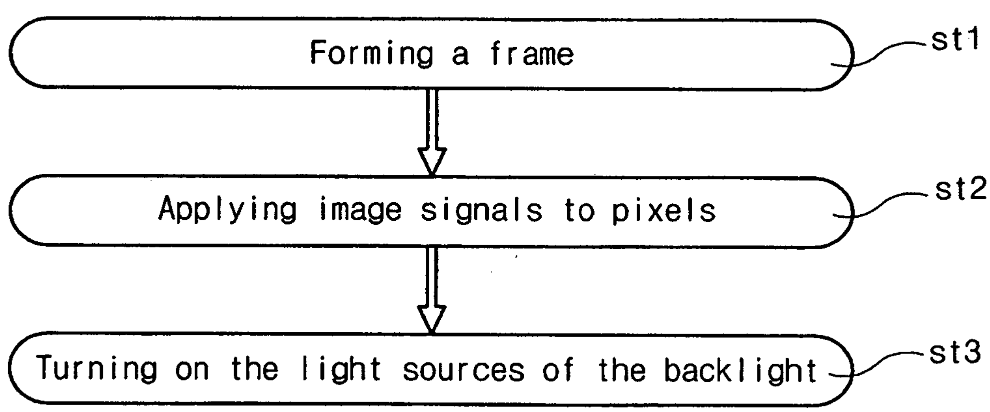
[Fig. 1]



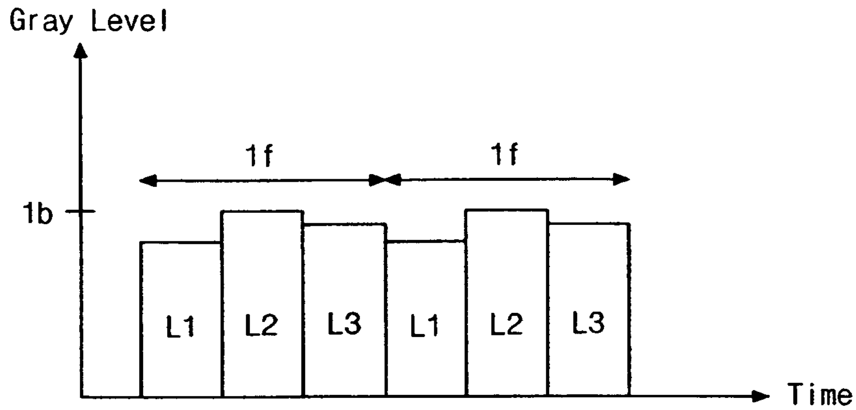
[Fig. 2]


60
61
1
64
65
62
70
T
67
66
1
R
G
B
72

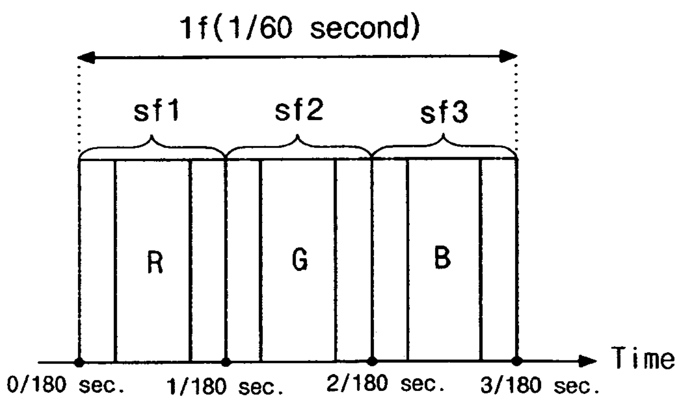
[Fig. 3]


Forming a frame
st1
Applying image signals to pixels
st2
Turning on the light sources of the backlight
st3

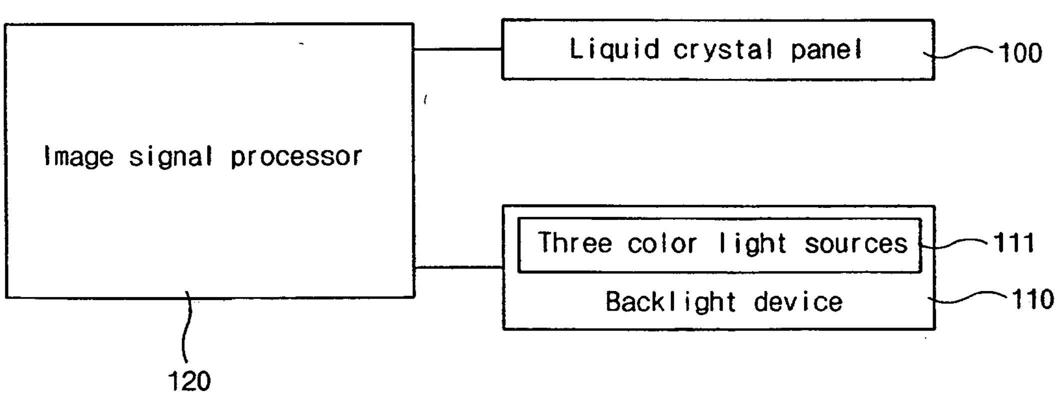
[Fig. 4]



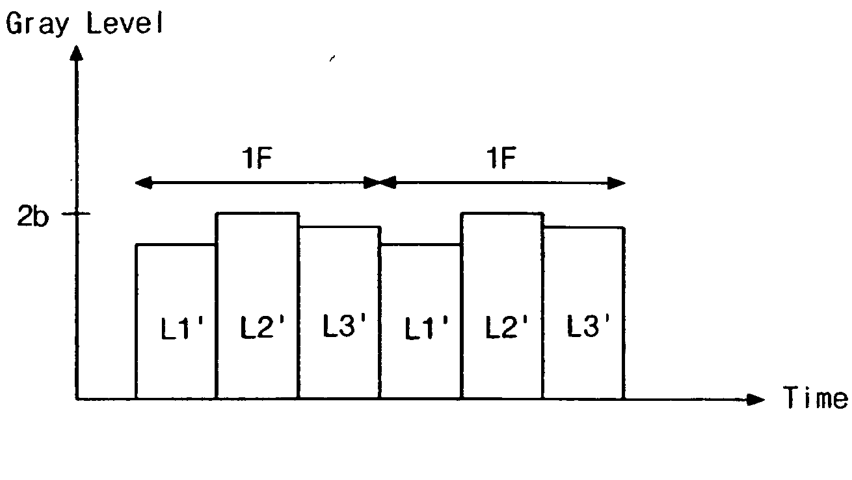
[Fig. 5]



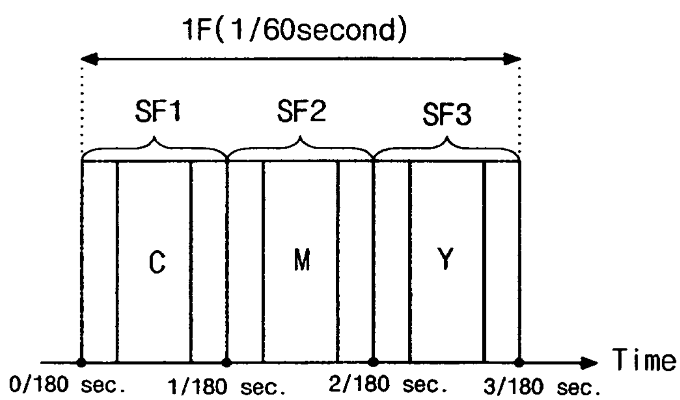
[Fig. 6]



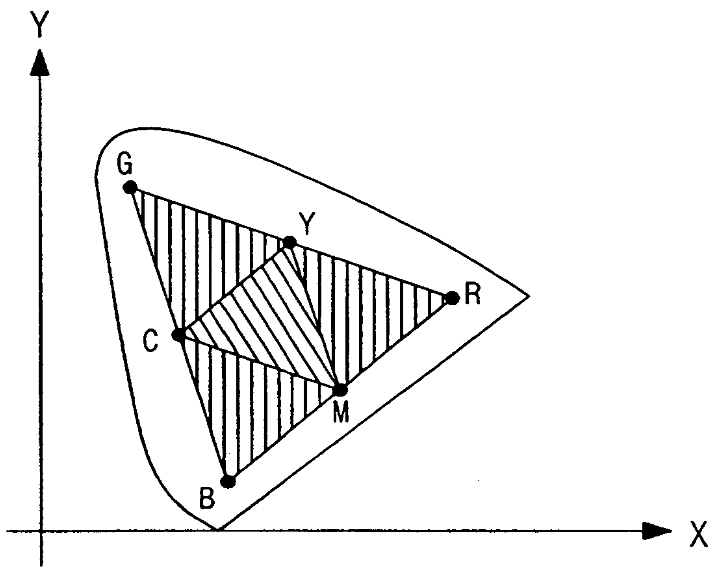
[Fig. 7]


Gray Level
1F
1F
2b
L1'
L2'
L3'
L1'
L2'
L3'
Time

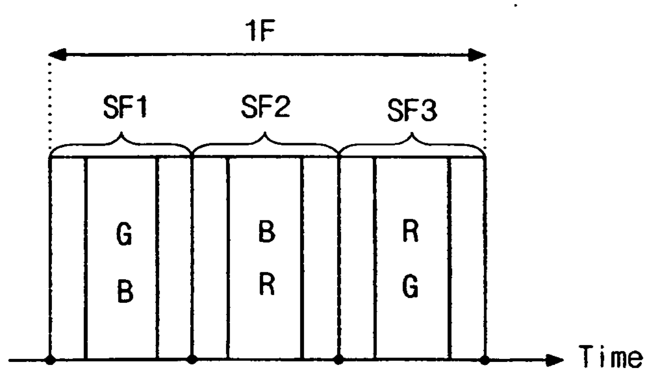
[Fig. 8]


1F(1/60second)
SF1
SF2
SF3
C
M
Y
Time
0/180 sec.
1/180 sec.
2/180 sec.
3/180 sec.

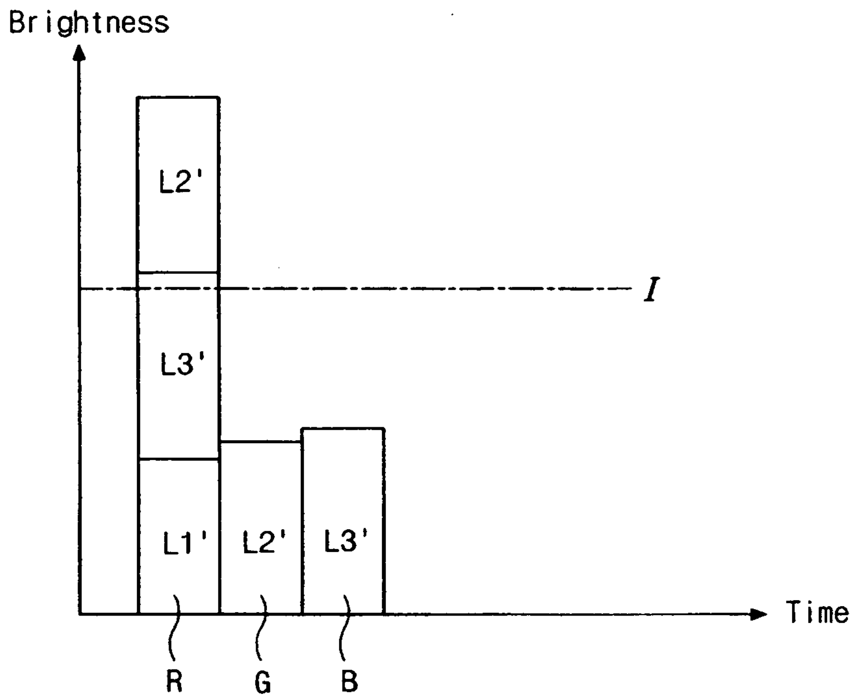
[Fig. 9]



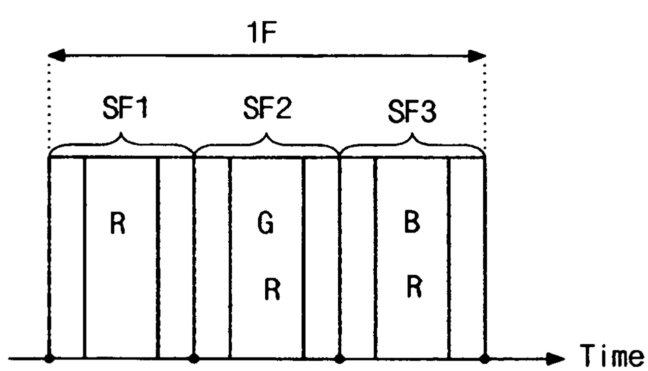
[Fig. 10]



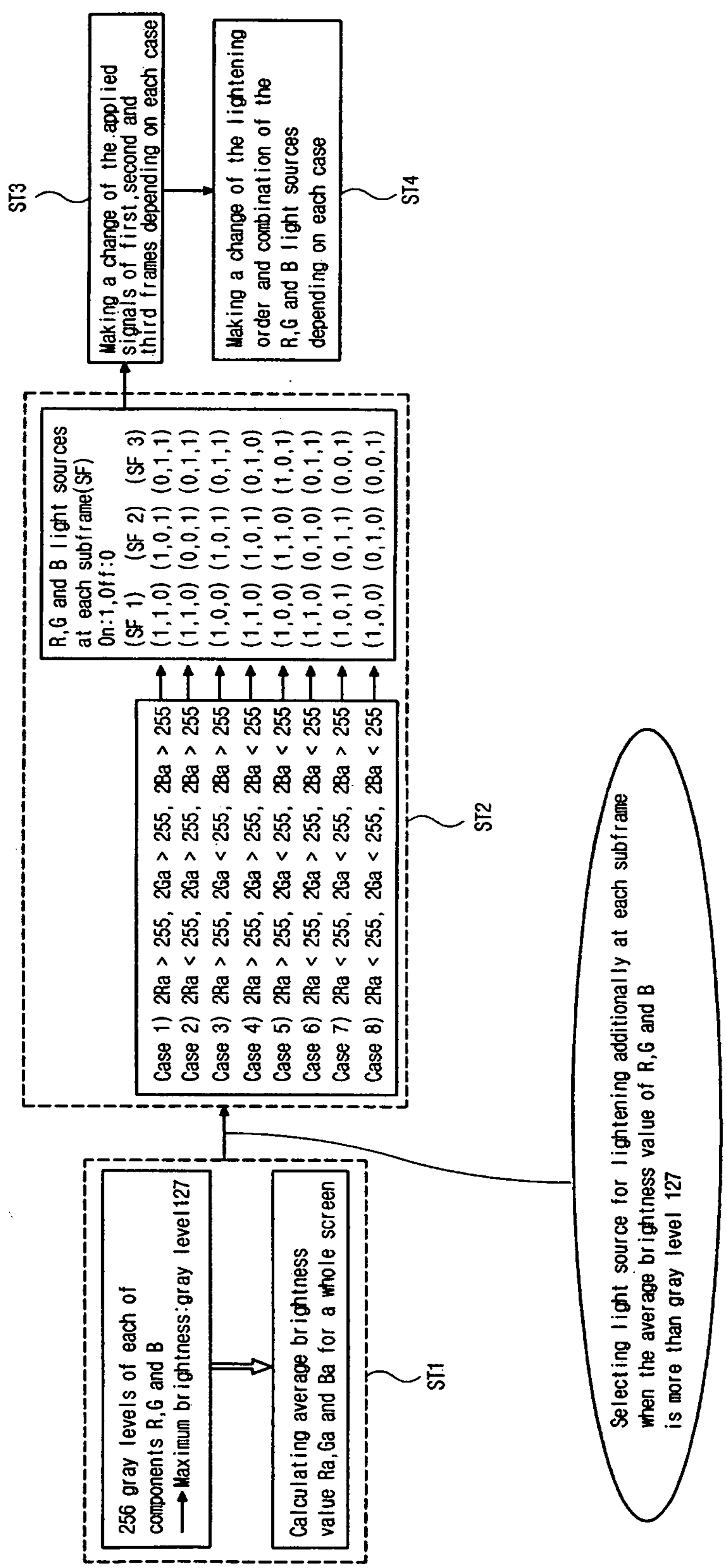
[Fig. 12]



[Fig. 13]



[Fig. 14]


256 gray levels of each of components R,G and B
→ Maximum brightness:gray level127
Calculating average brightness value Ra,Ga and Ba for a whole screen
ST1
Selecting light source for lightening additionally at each subframe when the average brightness value of R,G and B is more than gray level 127
Case 1) 2Ra > 255, 2Ga > 255, 2Ba > 255
Case 2) 2Ra < 255, 2Ga > 255, 2Ba > 255
Case 3) 2Ra > 255, 2Ga < 255, 2Ba > 255
Case 4) 2Ra > 255, 2Ga > 255, 2Ba < 255
Case 5) 2Ra > 255, 2Ga < 255, 2Ba < 255
Case 6) 2Ra < 255, 2Ga > 255, 2Ba < 255
Case 7) 2Ra < 255, 2Ga < 255, 2Ba > 255
Case 8) 2Ra < 255, 2Ga < 255, 2Ba < 255
ST2
R,G and B light sources at each subframe(SF)
On:1,Off:0
(SF 1) (SF 2) (SF 3)
(1,1,0) (1,0,1) (0,1,1)
(1,1,0) (0,0,1) (0,1,1)
(1,0,0) (1,0,1) (0,1,1)
(1,1,0) (1,0,1) (0,1,0)
(1,0,0) (1,1,0) (1,0,1)
(1,1,0) (0,1,0) (0,1,1)
(1,0,1) (0,1,1) (0,0,1)
(1,0,0) (0,1,0) (0,0,1)
ST3
Making a change of the applied signals of first,second and third frames depending on each case
Making a change of the lightening order and combination of the R,G and B light sources depending on each case
ST4